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etometer. The following table gives the essential data for the interval of 6 years, 9 months and 6 days with the increment from leap years:

NO.	<i>L</i> cm.	DIAM. INSIDE cm.	AREA cm ² .	DATE	INTERVAL <i>t</i> × 10 ⁸ SEC.	<i>h</i> cm.	10 ⁸ $\frac{dh}{dt}$	10 ¹² κ
I	20.0	0.55	0.24	{ 1914- 3-20 1920-12-26	2.14	{ 10.12 9.89	1.07	1.10
II	15.7	0.82	0.53	{ 1914- 3-20 1920-12-26	2.14	{ 7.59 7.22	1.73	1.87

The two values of κ found are of the same order, but the one for tube II is definitely larger than the one for tube I. This may be due to infinitesimal difference in the separated gases (a, a') of the tubes. But since the tube II has a shorter (L) and wider column, and a meniscus nearer the bend, it is more probable that thermal correction is the cause of the difference; for the inside sectional area of II is about 2.2 times larger than that of I. The data obtained for κ with a cylindrical cartesian diver (Carnegie Publications, No. 186, Washington, 1913, p. 21) about 3 cm. in diameter of 7.05 cm². in area, are enormously larger than the above, reading $\alpha = 90 \times 10^{-12}$. The result is in keeping with the enormously larger area and consequent effectiveness of the solution-temperature mechanism which I have described in the preceding paper.² Whether in case of tube I, a condition of true diffusion has been reached will have to be ascertained in the lapse of further years. Meanwhile the question whether a long slender cartesian diver may not obviate the discrepancies hitherto encountered is worth consideration.

¹ Advance note from a Report to the Carnegie Institution, Washington, D. C.

² These PROCEEDINGS, 6, 1920 (495-8).

THE INFLUENCE OF AGE ON FERTILITY IN SWINE ¹

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In the breeding of domestic animals the problem of fertility is of prime importance. The neglect of this essential factor has again and again caused breeders disappointments and often heavy economic losses. Thus it is desirable to study this chapter of the physiology of reproduction thoroughly and to examine the factors, internal and external, that affect the ability to produce offspring.

During an investigation on these subjects, in this laboratory the results of which are soon to be published, the writer has been confronted

with the question of the influence of age of the sow on the size of her litters. Although a number of records on this and similar subjects have been published from time to time, the writer is of the opinion that the special qualities of his material, and the mathematical treatment of it that it is possible to employ, justify this further publication.

In going over the literature on the influence of age on fertility in mammals, a number of records bearing on the question can be collected. Sarah V. Jones and James E. Rouse¹⁰ have in a recent paper give an extensive summary of the literature, to which paper I only need to refer for further information.

The records published are of two different kinds. First: results of experiments chiefly with rats (King¹¹), rabbits (Hammond⁸), and guinea-pigs (Minot¹⁴). The experiments on swine by Mumford¹⁵ (1917) are of further interest in this connection.

The second group consists of statistical investigations generally using as material the numerous records given in the herd books of the different breeds of domestic animals.

Carlyle and McConnell,⁶ Pearl,¹⁶ Bell,^{3,4} Humphrey and Kleinheinz,⁹ Jones and Rouse¹⁰ give records showing that the percentage of multiple births in sheep increases with age up to five years and then again declines. Pearl¹⁶ and Jones and Rouse¹⁰ give similar data for cattle showing a steady increase in the percentage of twin births with age.

Swine have often been subject to investigations of this kind. One of two sources of error have always been present in these. 1. The number of individuals involved have been so limited as to make dependable results unobtainable, or 2. The method of computing has been so rough as to give room for the effect of selection. The usual way of approaching the problem has been to take from herd book records of all available litters and to refer them to the age of their mothers at their birth. In this way it is possible to get a great number of litters from young sows but rather few from older ones as the less desirable animals are disposed of early. The older sows represent only a selected group of the best of those recorded at an early age, and the average size of litters at different ages of the sows are for that reason not directly comparable. Owing to these difficulties the results are very contradictory and uncertain. Rommel¹⁸ found a steady increase in size of litter from one to five years. Frölich and Georgs⁷ report a maximum in the second litter and then a decrease in size of the litters. Machens¹² claims a maximum at the fourth litter. Carmichael and Rice⁵ give a table showing an increase in fertility to the third year followed by a decrease.

2. The material used in this investigation consists of 134 sows of native Danish breed² which *all* have records from all of their first ten litters. The

records are taken from the Danish herd book Vols. V and VII. All these sows have been kept in state-supervised *breeding centres* under uniform conditions and care. They have all farrowed the first time at about one year of age and from then on been bred regularly producing ca. $2\frac{1}{4}$ litter per year, practically without regard to season. The successive litters will for that reason be highly correlated with age, but it seems most convenient to use the litter-number as unit. The average of all litters, being 11.5 pigs, is far above the average shown by swine of the American type, and although these 134 sows undoubtedly are selected group, the great fertility is one of the outstanding and valuable qualities of the breed.

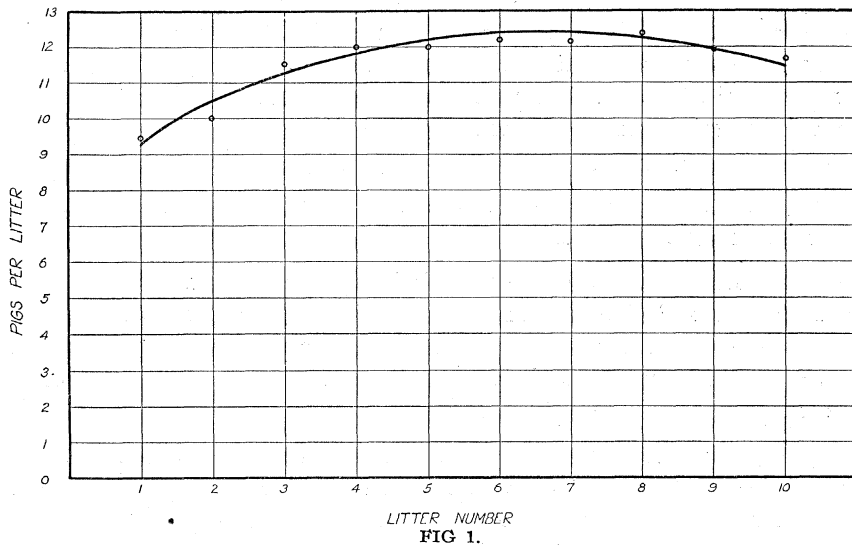


FIG 1.

The dots indicate the actual found averages for litter-size in the first ten litters. The curve is fitted to these values.

In the second column of table 1 the average sizes of the successive ten litters are given.

TABLE I		
LITTER NO.	AVERAGE SIZE OF LITTER	THEORETICAL SIZE OF LITTER
1	9.45	9.25
2	10.01	10.42
3	11.50	11.24
4	12.01	11.81
5	11.99	12.19
6	12.16	12.38
7	12.13	12.39
8	12.34	12.24
9	11.90	11.92
10	11.66	11.43
Average	11.52	11.53

Plotting the series of average values over a base indicating the successive generations (fig. 1) we see that they show an increase in fertility

with age to a certain point followed by a decline. An empirical curve following these plotted points shows a type familiar to us from other biological problems. It is in fact a logarithmic curve. Pearl¹⁷ has shown that the changes in milk flow with age in dairy cattle follow such a logarithmic curve and he has determined its equation.

The writer has now proceeded to form the equation relating fertility to age in the material at hand, and has in the calculations used the method of moments (Miner¹³).

The general form of the equation is

$$y = a + bx + cx^2 + d \log x$$

where y denotes the size of litter and x the ordinal litter number.

In this special case the equation has been calculated to be the following

$$y = 8.414 + 0.915x - 0.078x^2 + 1.627 \log x.$$

By solving the equation for the values of x ranging from 1 to 10 the theoretical average size of the successive litters has been determined. These values are given in the third column of table 1 and they are used in plotting the curve in figure 1. This curve shows a satisfactory agreement with the empirical figures plotted out.

By putting $dy/dx = 0$ and solving for x the litter of maximum size is found to be 6.56th in order.

Summary.—1. Records from 134 sows of native Danish breed all having ten litters to their credit show an increase in fertility up to the 6.56 point in litter order followed by a decrease.

2. The curve relating fertility to age is logarithmic, its equation is calculated, and the curve fitted.

¹Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 35.

²The native Danish breed is a white, fertile and hardy hog of bacon type, producing sometimes crossed with Yorkshire boars—the great proportion of the choice bacon exported from Denmark to England.

³Bell, A. G. 1904. The multi-nippled sheep of Beinn Bhreagh. *Science, N. S.*, **19**.

⁴Bell, A. G. 1912. Sheep breeding experiments on Beinn Bhreagh. *Ibid.*, **34**.

⁵Carmichael, W. J. and John B. Rice. 1920. Variation in farrow: With special reference to birth weight of pigs. *Univ. Illinois, Agric. Exp. Sta., Bull.* **226**.

⁶Carlyle, W. L. and T. F. Mc Connell. 1902. Some observations on sheep breeding from the Experiment Stations flock records. *Univ. Wisconsin, Agric. Exp. Sta., Bull.* **95**.

⁷Frölich und Georgs. 1911. Fruchtbarkeit und Geschlechtverhältnis beim weissen Edelschwein. *Jahrbuch für wissenschaftliche und praktische Tierzucht*, **6**.

⁸Hammond, John. 1914. On some factors controlling fertility in domestic animals. *J. Agric. Sci.*, **6**.

⁹Humphrey, G. C. and F. Kleinheinz. 1907. Observations on sheep breeding from records of the university flock. *24th Ann. Rep. Wisconsin Agric. Exp. Sta.*

¹⁰Jones, S. N. H. and J. E. Rouse. 1920. The relation of dam to observed fecundity in domestic animals. I. Multiple birth in cattle and sheep. *J. Dairy Sci.*, **3**.

- ¹¹King, H. D. 1916. The relation of age to fertility in rat. *Anat. Rec.*, **11**.
- ¹²Machens, A. 1915. Fruchtbarkeit und Geschlechtsverhältnisse beim veredelten Landschwein. *Berliner Tierärztliche Wochenschrift*, **31**.
- ¹³Miner, J. R. 1915. Fitting logarithmic curves by the method of moments. *J. Agric. Res.*, **3**.
- ¹⁴Minot, C. S. 1891. Senescence and rejuvenescence. First paper: On the weight of guinea pigs. *J. Physiol.*, **12**.
- ¹⁵Mumford, F. B. 1917. *The Breeding of Animals*.
- ¹⁶Pearl, R. 1913. Note regarding the relation of age to fecundity. *Science, N. S.*, **37**.
- ¹⁷Pearl, R. 1914. On the law relating milk flow to age in dairy cattle. *Proc. Soc. Exp. Biol. Med.*, **12**.
- ¹⁸Rommel, G. M. 1907. Inheritance of litter size in Poland China sows. *American Breeders Report* **3**.

VARIATION AND INHERITANCE IN SIZE IN *TRYPANOSOMA LEWISI*¹

1. LIFE-CYCLE IN THE RAT AND A STUDY OF SIZE AND VARIATION IN "PURE LINE" INFECTIONS²

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The flagellate, *Trypanosoma lewisi*, is a non-pathogenic blood parasite occurring in various species of rats all over the world. It is known to be transmitted from rat to rat by the rat flea. This trypanosome was selected for the present work because it occurs in the latitude of Baltimore and the vertebrate and invertebrate hosts can easily be reared in the laboratory.

The general plan of the present work on size in *T. lewisi* is to make a careful study of size and variability in a pure line and then with this background to attempt to explain the facts observed in infections occurring in nature. After a pure line infection was obtained the following questions were attacked: (1) What are the mean and the coefficient of variation? (2) Does growing the same "pure line" in different vertebrate hosts cause significant differences in the mean size or in the coefficient of variation? (3) Does passage of the "pure line" through the invertebrate host cause significant differences in the mean or coefficient of variation? This question gives us a chance to test the possibility that passage of the "pure line" through the invertebrate host may cause a splitting up of the "pure line" into heritably diverse lines. After a study is made of these questions we can attack the final one: (4) Does an infection occurring in nature consist of a large number of "pure lines" such as has